

Vulnerability Assessment of Rodriguez, Rizal towards the development of a Community-Engaged Flood Risk Management System

Jeffrey Bancifra

Environmental Management Bureau – National Capital Region, Philippines

Correspondence: jbancifra0078@mc-knoller.edu.ph , jeffrey.bancifra@yahoo.com

SUBMITTED: 10 May 2026; REVISED: 6 June 2026; ACCEPTED: 9 June 2026

ABSTRACT: Rodriguez (Montalban), a municipality in the Philippines located on the southern slope of the Sierra Madre Mountain Range, is characterized by predominantly mountainous terrain, with approximately 83% of its land consisting of uplands, hills, and steep slopes. Despite these extensive upland areas, most urbanized zones are situated in flood-prone locations. Climate change has further exacerbated flood risks by increasing the intensity and frequency of precipitation events. This study assessed the vulnerability of communities in selected barangays of Rodriguez, Rizal, using a combination of Geographic Information System (GIS) mapping, the Hydrologic Engineering Center’s River Analysis System (HEC-RAS), surveys, and Key Informant Interviews (KIIs), alongside considerations of social engagement and the thematic areas of the National Disaster Risk Reduction and Management Framework (NDRRMF). The findings indicate that Rodriguez exhibits a moderate level of flood vulnerability, with flood risk management measures being predominantly reactive rather than preventive. Residents identified deforestation, particularly quarrying activities, as the primary contributor to flooding, whereas the Local Government Unit (LGU) identified urbanization as the main driver. However, these perspectives are not mutually exclusive. Furthermore, HEC-RAS simulations revealed that areas with steeper slopes and locations adjacent to deforested zones experience higher flood velocities than other parts of the floodplain. Motivations for community engagement in flood risk management were largely influenced by perceptions of good governance (35.57%) and shared values (33.08%), while financial incentives for key volunteers were found to have only a marginal influence (12.31%). Based on these findings, the study developed the FLOOD GATES (Flood Governance Anchored in Transparency and Engaged Society) System, a community-engaged flood risk management model designed for mainstreaming within LGUs. By integrating technical hydrological data with community-generated inputs, the FLOOD GATES System facilitates proactive participation across all phases of flood risk management, including prevention, mitigation, preparedness, response, and rehabilitation. The model also enhances adaptive capacity by promoting transparency, accountability, and community empowerment.

KEYWORDS: Flood risk management; climate change; social engagement; local government; Rodriguez, Rizal; HEC-RAS

1. Introduction

This study aimed to address the flood risk vulnerability of Rodriguez, Rizal. It is a first-class municipality in the Province of Rizal, Philippines. Rodriguez has eleven (11) barangays. Eight (8) of these are urban barangays, which are Balite, Burgos, Geronimo, Manggahan, Rosario, San Isidro, San Jose, and San Rafael. On the other hand, three (3) barangays, namely Macabud, Mascap, and Puray, are considered rural [1]. The municipality has a population of 443,954 as of the latest census in 2020. The population represents 13.33% of the total population of Rizal (3,330,143). It is situated at approximately N 14° 39' 7.272", E 121° 4' 39.3708" in Luzon. The elevation is an estimated average of 112 meters above mean sea level [1]. However, most low-lying areas, and even some areas with high elevation, are known to be affected by the effects of climate change, such as strong typhoons and flooding. The northern part of the Marikina River Valley was characterized by slopes and was drained by the Wawa River, Marikina River, Burgos River, and other small streams. Rising from the northeast, these natural drainage systems generally flow towards the southwest [1]. Rodriguez (Montalban) is situated within the southern slope of the Sierra Madre Mountain Range. It has a very rough topography and is mountainous in nature. Based on data from the Bureau of Soils and Water Management (BSWM), approximately 83% of its land area is composed of upland areas, hills, and mountain ranges with steep slopes and rugged terrain. Only a small portion has low-lying level terrain to moderately sloping and rolling lands [2]. Despite having more upland areas, most of these are rural areas. Nonetheless, urbanized areas are within flood-susceptible zones.

Flood events are not rare in the municipality. To exemplify, from August 6 to 8, 2012, the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) rated the rainfall in Metro Manila, including the town of Rodriguez, as heavy to intense (10.0 to 30.0 mm/hr rainfall), which eventually flooded the low-lying areas and resulted in the evacuation of 6,510 families or 32,559 individuals [2]. On July 24-25, 2024, Typhoon Carina and the enhanced Southwest Monsoon caused flash floods in various parts of the Municipality of Rodriguez, which affected 32,029 families or a total of 155,002 individuals, and damaged 5,680 houses [3]. To mention are the other recorded weather disturbances that also caused damage in the past, such as Typhoon Ondoy in 2009 that caused floods exceeding six feet [4]; heavy rains and flash floods brought by *Hanging Habagat*, or the Southwest Monsoon, in 2018 that affected seven barangays in Rodriguez [5]; and floods caused by Typhoon Carina in 2024, which resulted in the declaration of a state of calamity in Rodriguez [6] due to many communities experiencing power outages and water shortages [7]. Based on the 25-year flood hazard map from the LiDAR Portal for Archiving and Distribution, most barangays in Rodriguez have medium to high flood susceptibility, particularly Burgos, San Jose, San Rafael, San Isidro, and Balite [8]. These data indicated a high flood risk to human safety and property within the location of the study.

According to the 2021 Philippines Disaster Management Reference Handbook, the Philippines is located on the Pacific Ring of Fire and along the Pacific typhoon belt [9]. This means that the country experiences many forms of natural hazards, such as typhoons, earthquakes, floods, volcanic eruptions, landslides, and fires. Many bodies of water surround the Philippines. This increases the country's hydrological risk. According to research cited by the World Bank, various organizations studied flood exposure in 188 countries. The Philippines ranked 16th, with 29.0% of the population exposed to flood risk [10]. Breda et al. (2023)

mentioned that a warmer atmosphere can hold more water, which consequently intensifies the hydrological cycle [11]. The hydrological cycle is expected to intensify with global warming, which likely increases the intensity of extreme precipitation events and the risk of flooding [12]. The Paris Agreement sets out a global framework to avoid dangerous climate change by limiting global warming to well below 2° Celsius and pursuing efforts to limit it to 1.5°C [13]. This agreement was adopted at the Paris Climate Conference (COP21) in December 2015. All parties to the Paris Agreement committed to strengthening the global response to climate change by increasing the ability of all to adapt, build resilience, and reduce vulnerability. The concept of vulnerability came from various disciplines, and its definition varies accordingly. However, most literature characterizes vulnerability according to the basic formula: Risk + Response = Vulnerability [14]. Generally, vulnerability is the degree to which a system is susceptible to or unable to cope with the adverse effects of climate change [15], specifically, in this study, floods. For Birkmann (2006), the concept of vulnerability has five key spheres [16]. It shows that vulnerability scope can be widened from the first sphere that shows intrinsic vulnerability to the likelihood to experiencing harm in the second one. The third concept is vulnerability as a dualistic approach of susceptibility (risk) and coping capacity. Meanwhile, the fourth and fifth show vulnerability as a multiple structure and multi-dimensional vulnerability, respectively [16].

There are two ways to protect lives and properties from flooding: keep floodwater away from people (mainly through structural measures); and keep people away from floodwater (mainly through non-structural measures) [17, 18]. Structural measures include any physical construction to reduce or avoid possible impacts of hazards or the application of engineering techniques to achieve hazard resistance and resilience in structures or systems, while non-structural measures are any measures not involving physical construction that use knowledge, practice, or agreement to reduce risks and impacts, in particular through policies and laws, public awareness raising, training, and education [17, 19]. Though structural and non-structural ways are considered in flood risk management [17, 25], community engagement has its limitations. Studies of Wu et al. [20] and Mugume and Butler [21] focused on structural flood management, while Miranda et al. [22] shows skepticism in the changes in runoff patterns caused by the built environment [22].

In the mentioned related literature and studies, the communities and their flood risk management participation were described. Batuca et al. [23] and Owukio et al. [24] merely recommended public participation and community collaboration, respectively, in flood events. Also, Owukio et al. [24] recommended the use of both structural and non-structural flood risk management. The mentioned studies are useful references for flood management. However, the literatures did not quantify, though some characterized, the level of engagement and perception in flood risk management of vulnerable communities, specifically in the subject local government unit. The general objective of this study is to conduct a comprehensive vulnerability assessment and develop a Community-Engaged Flood Risk Management System to address hydrological risks of selected Barangays in Rodriguez (Montalban), Rizal, as a basis for planning and managing flood risks in the context of climate change adaptation. Meanwhile, the specific objectives are a) to assess the flood risk impact level on the communities in the selected barangays of Rodriguez, Rizal, b) to determine the adaptive capacity of the vulnerable communities to cope with the impacts of flooding in the municipalities' flood-prone areas, c)

to determine the management capacity of the Local Government Unit (LGU) in flood events, d) to establish criteria indicators, such as but not limited to flood susceptibility and various community engagement activities in flood risk management, for an effective Community-Engaged Flood Risk Management (CEFRM) System for flood-vulnerable communities of the municipality; and e) to develop a CEFRM System for LGUs in the Philippines.

The WMO has its Community-Based Flood Management Tool, which emphasizes the importance of community participation as part of flood management [25]. Despite the fact that it discusses the level of participation of the different stakeholders in different stages of flood management (prevention and preparation, preparedness, response, recovery) and delineates various community groups, which are residents, community leaders, water users, and the private sector [25], the tool does not present quantified data or further studies of its applicability for Philippine LGUs. The Philippines has its existing law, RA 10121, which envisions transforming the Philippines from relief response to disaster risk reduction [26]. The country produced the NDRRMF, a national framework for disaster risk reduction and management. As per Bawagan (2011), the Philippines has a Community-Based Disaster Risk Reduction and Management Framework (CBDRMF) based on the NDRRMF [27]. Her study provided lessons on the implementation of NDRRMF in communities. Nonetheless, the study only enumerated and assessed sample projects relative to the implementation of NDRRMF in communities [27]. Dales et al. (2020) conducted phenomenological research within the context of Community-Based Disaster Risk Management in flood- and landslide-prone areas of residents in Bukidnon. This study provided a community-based disaster management model, which shows that a participatory process shall identify and assess the hazards that threaten the community [28]. The existing CBFMMP of the province of Bulacan identified flood hazards in the province and is mainly concentrated on flood prevention and mitigation, such as planning and early detection [18]. The existing models have their advantages; yet the CBDRM model in Bukidnon is not fully realized by the local government, while the CBFMMP in Bulacan is mainstreamed but does not include rehabilitation and recovery. Moreover, both models are for the provincial level and may be too broad to be implemented in smaller communities. This study assessed the impacts of flood factors which are elevation, river network, flood susceptibility of smaller communities and how the residents perceive both the risks and their engagement to flood risk management.

2. Materials and Methods

2.1. QGIS and Hydrologic Engineering Center's River Analysis System (HEC-RAS)

A mixed (qualitative-quantitative) research method was used for this study. The data were gathered through triangulation via identifying flood susceptibility (using GIS maps, population exposure to flood hazard, and Hydrologic Engineering Center's River Analysis System [HEC-RAS]), surveys, interviews, and observation. The parameters and corresponding processes for the generated GIS maps made and used for each of the barangays within the study area includes Elevation Maps that used the Digital Elevation Model (DEM) for the municipality of Rodriguez, then narrowed down the imagery to the study areas: Burgos, San Jose, and Isidro; River Network Maps – delineated waterways were extracted from the Humanitarian Data Exchange with additional digitization for rivers and creeks seen in the topographic map; and

the Flood Hazard Maps - generated using LIDAR shapefile data from the DOST-UP DREAM and Phil-LIDAR. The flood hazard maps illustrate the inundation extents in the area if the actual amount of rain exceeds that of a 25-year return period. The rainfall intensity duration is 373.60 mm within 24 hours [8], setting flood level at maximum. A base map (Figure 1) was initially generated by the researcher to provide the primary location of the subject municipality and its barangays, including the identified political boundaries.

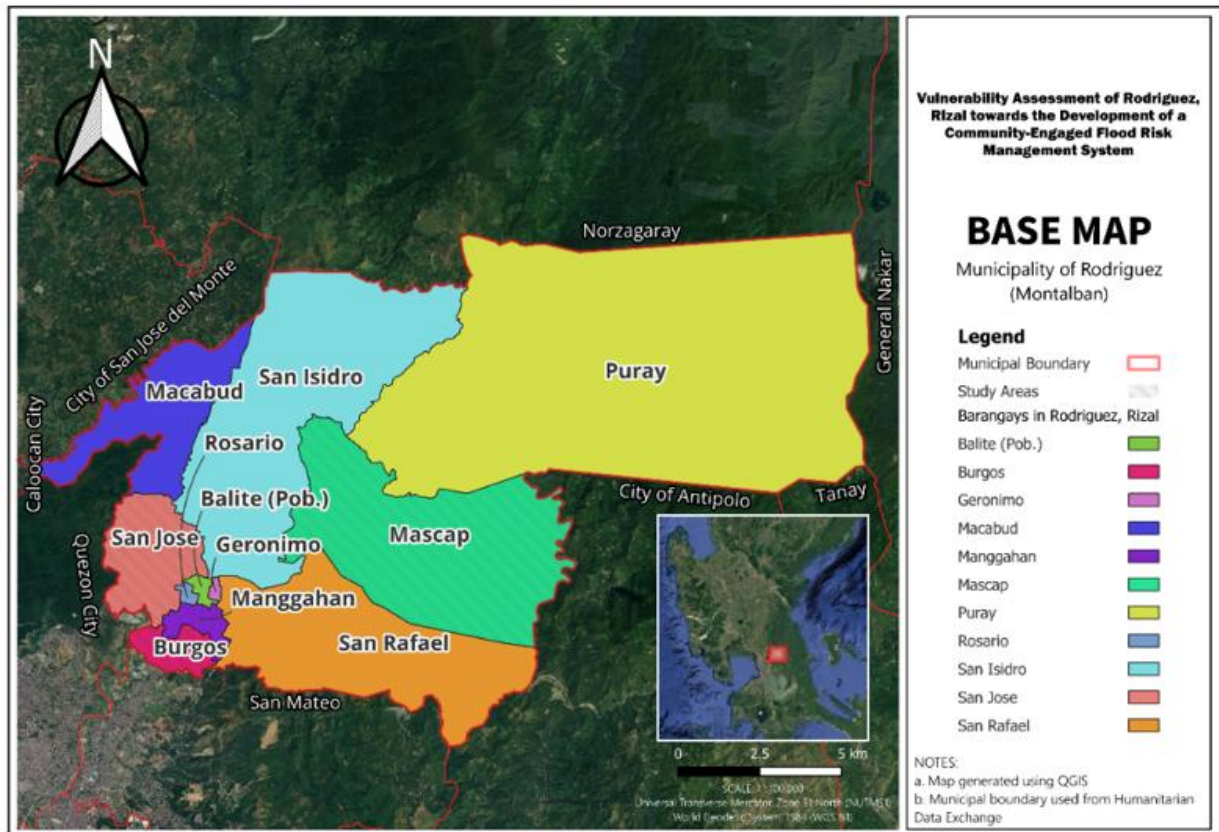


Figure 1. Generated base map of Rodriguez, Rizal.

The sample barangays were selected according to the three points of the average topographic elevation of residential areas, hydrological profile through Geographic Information Systems (GIS) and geographic satellite visualization imagery, existing flood risk areas, and population prone to flooding. The selected barangays represents the downstream, midstream, and upstream of the water body. Table 1 summarizes the criteria used to select representative barangays for the study based on elevation, hydrological characteristics, flood-prone population, and the number of households affected by flooding. Barangays were grouped into downstream, midstream, and upstream zones to reflect variations in flood exposure across the watershed. Based on the combined indicators, Burgos, San Jose, and San Isidro were selected as representative study sites for the downstream, midstream, and upstream zones, respectively. These barangays provided contrasting flood risk conditions for assessing community vulnerability and flood risk management practices.

Table 1. Site selection criteria.

Elevation Group of Barangays According to Water Flow Stages	Barangay	Average Elevation in Meters Above Sea Level (MASL)	Population Exposure (PSA, 2020) Prone to Flood (MGB, 2018)	Household affected (DSWD, 2019)	Selected Barangays Based on the Indicators
Downstream approx. Below 25.9 MASL	Burgos	23.48	23,370 out of 51,444 (45.428%)	4,674 out of 10,288	BURGOS
	Rosario	23.70	3,433 out of 6,866 (50.000%)	687 out of 1,373	
	Balite	25.44	3,584 out of 8,534 (41.997%)	717 out of 1,707	
Midstream approx. 26-200 MASL	Manggahan	26.34	5,944 out of 17,851 (33.298%)	1,189 out of 3,570	SAN JOSE
	Geronimo	27.58	2,170 out of 6,764 (32.082%)	434 out of 1,353	
	San Jose	53.74	34,362 out of 141,819 (24.229%)	6,872 out of 28,363	
	San Rafael	184.42	675 out of 31,922 (2.115%)	135 out of 6,384	
Upstream approx. above 200 MASL	Macabud	190.33	76 out of 10,726 (0.709%)	15 out of 2,145	SAN ISIDRO
	San Isidro	226.18	6,725 out of 159,612 (4.213%)	1,345 out of 31,922	
	Mascap	259.86	14 out of 4,708 (0.297%)	3 out of 942	
	Puray	672.18	3 out of 3,708 (0.081%)	1 out of 742	

2.2. Survey.

A formal survey questionnaire was prepared. The instrument included both closed-ended and open-ended questions regarding the respondents' perceived flood risks and their engagement in implementing the flood risk management that the LGU administers in the communities. This was to get both quantitative and qualitative data concurrently. This study assessed the flood vulnerability in Rodriguez with three (3) sample barangays of Rodriguez with a dualistic approach—risk and adaptive capacity [16].

2.3. Key informant interviews and observation.

Key Informant Interviews (KIIs) or discussions were conducted with the representatives of the Climate Change Service of the Department of Environment and Natural Resources (DENR), Pamantasan ng Lungsod ng Valenzuela (PLV), local government, particularly the Municipal Executive Office (e.g., Mayor's Office/representative), Disaster Risk Reduction and Management Office (MDRRMO), and Municipal Environment and Natural Resources Office (MENRO), with concerned barangay LGU officials. This is to discuss the existing adaptive capacity measures for flood hazards. An interview had a duration of thirty (30) minutes to one (1) hour. By asking questions, information from the LGU officers shall be gathered to know the existing climate change adaptation measures, particularly for floods. Observation consists of taking field notes on the participants in the interviews conducted.

2.4. Statistical analysis.

In this study, statistical methods were employed to analyze the data and measure the perceived level of flood risk, the level of community participation, and the assessment of the LGU's flood risk management. A Likert scale was used to quantify respondents' perceptions and interpretations of flood-related issues. Slovin's formula and percentage frequency distribution

were applied to determine the sample size, resulting in a total of 402 respondents (134 respondents per barangay). Respondents indicated their level of agreement or disagreement with a series of statements using an agree–disagree scale. The survey assessed the perceived level of flood risk and the level of community engagement across the four thematic areas of flood risk management: prevention and mitigation, preparedness, response, and recovery and rehabilitation. The Likert scale ranged from 0 (lowest) to 4 (highest), with corresponding engagement levels as presented in Table 2.

Table 2. Likert scale for the engagement of Rodriguez, Rizal residents.

SCORES	MEAN RANGE	DESCRIPTION
4	3.21 – 4.00	Very Engaged
3	2.41 – 3.20	Fully Engaged
2	1.61 – 2.40	Moderately Engaged
1	0.81 - 1.60	Slightly Engaged
0	0.00 – 0.80	Not Engaged at All

The collected responses were consolidated and analyzed using percentage frequency distribution to determine the Mean Flood Risk Impact Level and the Mean Adaptive Capacity of the communities through their engagement in flood risk management. After obtaining the frequency distributions, a dualistic vulnerability scoring approach was applied to assess the overall vulnerability of the selected barangays and their residents. The vulnerability index was calculated by combining flood risk impact levels (susceptibility) and adaptive capacity (engagement in flood risk management), as shown in Table 3.

Table 3. Flood vulnerability scoring of Rodriguez, Rizal from the survey.

Degree of Flood Risk Impact Level (Susceptibility) Score	Adaptive Capacity (Engagement in Flood Risk Management)					Vulnerability Index
	Highly Engaged (1)	Fully Engaged (2)	Moderately Engaged (3)	Slightly Engaged (4)	Not Engaged at All (5)	
High (3)	3	6	9	12	15	HIGH (11-15)
Medium (2)	2	4	6	8	10	MODERATE (6-10)
Low (1)	1	2	3	4	5	LOW (1-5)

2.5. Non-statistical analysis.

The non-statistical analyses conducted within the context of the four thematic areas of flood risk management (i.e., prevention and mitigation, preparedness, response, and recovery and rehabilitation) included narrative analysis, pattern identification, and expert opinion analysis..

2.6. Ethical considerations.

All data collected during the interviews were treated as strictly confidential. Respondents' names were not included in any publications, reports, or presentations resulting from this research unless explicit permission was granted. Participation was entirely voluntary, and respondents were free to decline answering any question or withdraw from the study at any time without any negative consequences.

3. Results and Discussion

3.1. Flood risk impact level.

For Objective 1 of this study, to determine the impact level of flood risks on the most vulnerable residents of Rodriguez, the researcher generated GIS maps of identified flood-susceptible areas by producing elevation maps. The results show that low elevation poses higher flood susceptibility. However, higher areas such as Barangay San Isidro are not exempt from flood risks. In addition to the maps, a survey was conducted among residents who experienced flooding to collect data relative to their perceived flood risk impact level. The flood risk level scoring was derived from the Supplemental Guidelines on mainstreaming Climate Change and Disaster Risks in the CLUP [15] of the Housing and Land Use Regulatory Board (HLURB, now Department of Human Settlements and Urban Development), wherein the flood height is multiplied by the assigned likelihood of occurrence and further simplified as 1, 2, and 3 for low risk, medium risk, and high risk, respectively, to provide more clarity for the respondents.

3.1.1. GIS/HEC-RAS simulation maps of the research locale.

Using the Hydrologic Engineering Center's River Analysis System (HEC-RAS), this study simulated flood inundation in Rodriguez, Rizal under a 10-year return period rainfall event occurring within a 24-hour period, similar to the flooding experienced during the 2025 Southwest Monsoon (Habagat). The simulation was conducted to identify the areas that would experience flooding first and to generate localized flood inundation maps for the selected barangays. These maps illustrate the areas most likely to be affected within 24 hours of a 10-year return period rainfall event (300.10 mm in 24 hours), as shown in Figure 2.

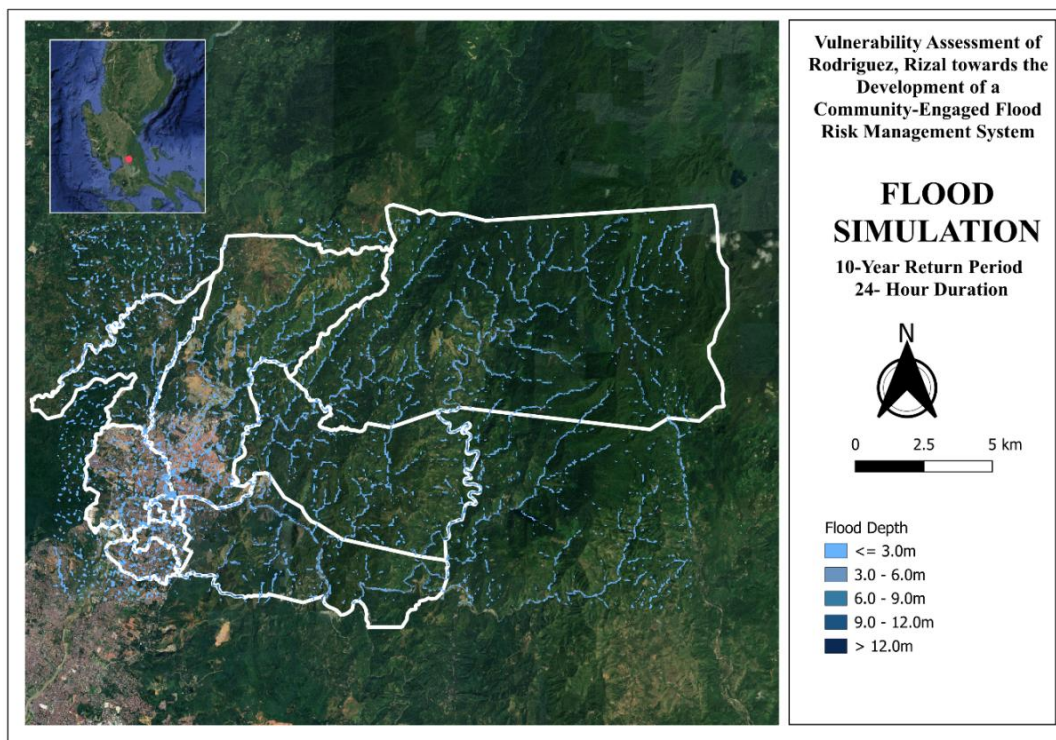


Figure 2. 10-Year return period flood within 24-hour period in Rodriguez, Rizal.

In Burgos, within 24 hours of rain in a 10-year return period, the first areas affected by flooding are Celina Homes IV, Dela Costa Homes V Phase, Estrella Heights Subdivision,

Sorrento Village, and areas near Becco Street. For Barangay San Jose, the prominent areas that experience flood inundation are along Riverside Road, Kasiglahan Village (Phases 1B, 1D, 1K, 1K1, and 1K2), Tagumpay Housing, areas near Lawaan Street, areas near Mabolo Street, and Sitio Sabah. In addition to the areas within San Jose, portions of the smaller barangays of Balite and Manggahan, adjacent to the Marikina River, are affected by flooding within 24 hours of heavy rainfall. In Barangay San Isidro, AFP Housing, East Bellevue Residences, portions of East Meridian Residences 1, portions of Double L, and portions of Eastwood Residences are among the first areas where floodwater rises. The simulation results shown in Figure 2 demonstrate the flood susceptibility of these areas and support the flood hazard maps developed by the Department of Science and Technology (DOST) and the Mines and Geosciences Bureau (MGB), as well as the exposure of residents within these zones. These findings were further substantiated by the perceived flood risks reported by residents during the survey. Furthermore, compared with the University of the Philippines Disaster Risk and Exposure Assessment for Mitigation (UP-DREAM) flood simulations, the present study considered not only maximum flood depth [8] but also the temporal progression of flooding and the time required for specific areas to become inundated.

3.1.2. Perceived flood risk impact.

The overall perceived flood risk impact level for Rodriguez, Rizal was classified as Medium Risk across all demographic groups, including age, sex, marital status, income, length of residency, and educational attainment. However, Barangay Burgos attained a High-Risk score, whereas Barangays San Jose and San Isidro were classified as Medium Risk. These findings suggest that lower elevations significantly influence residents' perceptions of flood risk. Consistent with the HEC-RAS simulation results presented in Figure 2, most areas that experienced flood inundation first were located near major water bodies. Furthermore, respondents frequently reported during interviews that nearby rivers and streams rapidly rise during periods of heavy rainfall.

3.2. Perceived adaptive capacity.

To address Objective 2, which aimed to determine the perceived adaptive capacity of residents to flood risks, the survey included questions related to community engagement in flood risk management activities. The findings indicate that residents possess a moderate adaptive capacity to flood risks. While respondents reported being fully engaged in flood response activities, their participation in prevention, mitigation, preparedness, and recovery efforts remained moderate. This suggests a greater reliance on reactive flood management measures rather than proactive risk reduction strategies..

3.3. Vulnerability scores.

The vulnerability assessment was conducted by calculating vulnerability scores for each selected barangay. The results showed that Barangay Burgos had a moderate vulnerability score (6), whereas Barangays San Jose and San Isidro each obtained a low vulnerability score (4). These scores were derived from the average perceived flood risk impact level and adaptive capacity based on residents' engagement in flood risk management activities, as determined through surveys and interviews. Respondents from Barangay Burgos perceived flood risk as

high, whereas respondents from Barangays San Jose and San Isidro perceived flood risk as moderate. Despite the higher perceived risk in Burgos, its adaptive capacity remained moderate. In contrast, residents of San Jose and San Isidro reported being fully engaged in flood risk management activities. Consequently, the Vulnerability Index classified Burgos as moderately vulnerable, while San Jose and San Isidro were classified as lowly vulnerable. Using the barangay-level values and the Vulnerability Scoring Formula developed by the Housing and Land Use Regulatory Board (HLURB) [15], the overall vulnerability scores were computed. Based on the combined susceptibility and adaptive capacity scores of the selected barangays, Rodriguez, Rizal was determined to exhibit an overall Moderate Flood Vulnerability Score.

3.4. Management capacity of the LGU.

To address Objective 3, which aimed to determine the management capacity of the Local Government Unit (LGU) during flood events, Key Informant Interviews (KIIs) were conducted. Based on the responses of four (4) LGU personnel and three (3) barangay responders, the Municipality of Rodriguez exhibited a low management capacity in terms of structural flood risk management. In contrast, its capacity for non-structural flood risk management was assessed as moderate. These findings suggest that while institutional mechanisms for preparedness, response, and coordination are relatively established, further investments in structural flood mitigation measures are needed to strengthen overall flood resilience.

3.5. Criteria indicators for a community-engaged flood risk management system.

To address Objective 4, which sought to establish criteria indicators for a community-engaged flood risk management system, including flood susceptibility and community engagement activities, narrative analysis and pattern identification were conducted. The findings revealed that most respondents perceived deforestation, particularly in mountainous areas, as the primary cause of flooding within the municipality. Several respondents also identified quarrying activities as a contributing factor. Despite these concerns, existing flood-related initiatives were primarily focused on information dissemination and flood response activities rather than preventive measures such as reforestation. The results further indicated that residents' motivation to participate in flood risk management was largely influenced by perceptions of good governance and shared community values. Financial incentives, such as cash allowances for key volunteers, were also identified as a motivating factor, although to a lesser extent. Respondents proposed several strategies for flood prevention and mitigation, with reforestation emerging as one of the most frequently suggested interventions. Nevertheless, current community engagement efforts remain concentrated on flood response activities, particularly evacuation, relief operations, and communication before and during flood events.

3.5.1. Identified cause of flooding.

Respondents identified deforestation (40.42%) as the primary cause of flooding in Rodriguez, Rizal, followed by clogged drainage systems (22.01%), proximity to waterways (18.41%), low elevation (11.44%), urbanization (7.34%), and other factors (0.36%). Based on respondents' field observations, quarrying and mining activities were frequently cited as major contributors

to flooding in the municipality. Supporting this perception, records from the Mines and Geosciences Bureau (MGB) IV-CALABARZON (2025) and the Environmental Management Bureau (EMB) (2021) identified eight (8) registered quarrying and mining sites within Rodriguez, Rizal [29, 30]. Five (5) of these sites are located in Barangay San Isidro. According to the Municipal Environment and Natural Resources Office (MENRO), quarry permits are issued by the MGB upon the recommendation of the Provincial Mining Regulatory Board (PMRB), subject to the submission of documentary requirements, including an Environmental Compliance Certificate (ECC) issued by the EMB. The LGU subsequently issues business permits upon verification of these permits and other regulatory requirements. Furthermore, the Municipal Planning and Development Office (MPDO), citing the Comprehensive Land Use Plan (CLUP) 2012–2022, stated that the existing quarry sites are located within designated quarrying zones. However, the possibility of future expansion of these areas was not ruled out.

Further evidence was provided by the HEC-RAS velocity simulation presented in Figure 3, which shows that floodwater velocities were highest in areas surrounding the identified quarry sites in Barangay San Isidro. The increased velocities can be attributed to the combined effects of steeper slopes and reduced forest cover. As illustrated in Figure 3, areas with less vegetation experienced more rapid surface runoff and greater flow velocities during flood events. The loss of forest canopy reduces rainfall interception and infiltration, allowing precipitation to reach the ground directly and increasing both the volume and velocity of runoff [31]. These findings support residents' perceptions that deforestation and land-use changes associated with quarrying activities may contribute to increased flood risks in the municipality.

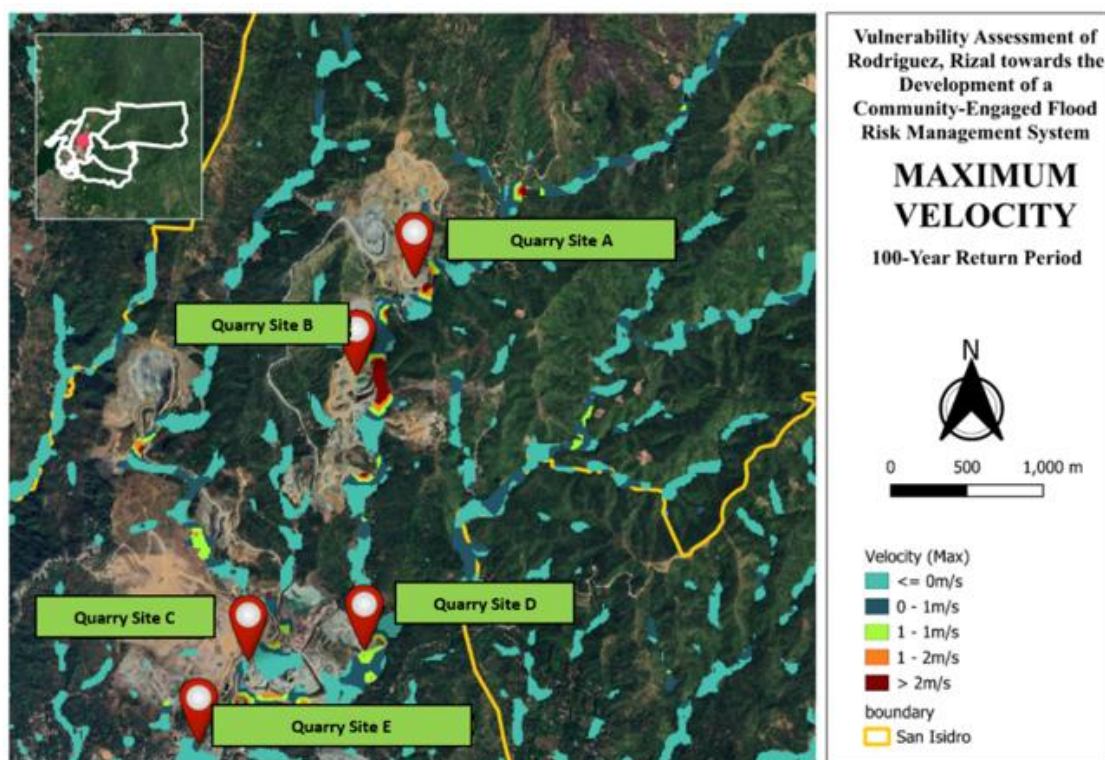


Figure 3. HEC RAS Velocity Map (zoomed to Quarry Sites in Barangay San Isidro).

Furthermore, using HEC-RAS simulation as shown in Figure 3, the velocity of floodwater near the determined quarry sites is maximum, affected by both higher slopes and less forested areas. The higher velocity is linked to the loss of forest canopy. When forests are

removed, rainfall reaches the ground directly, and water moves faster, leading to higher volume and higher velocity of surface runoff [31].

3.5.2. Motivation to engage in flood risk management.

As seen in Table 7, the motivation of residents to engage in flood risk management is mainly good governance (35.57%) followed by values (33.08%) and the provision of cash allowances for key persons/volunteers (12.31%). The identified main motivation of the residents in Rodriguez in engaging in flood risk management is good governance. This shows that the participants demand transparency and strict environmental policies. This is followed by instilled values, cash allowance, technological advancement, and incentives, respectively. Furthermore, residents are more socially engaged to local policies when they are benefiting together with their community [32, 33].

3.5.3. Pattern identification and narrative analysis.

Upon observation during surveying and participant interviews, the respondents who experienced floods are more enthusiastic about answering the survey and more emotional when giving suggestions or opinions. A few of the respondents are hesitant to provide details at first for fear of being red-tagged. However, the researcher assured that their answers would be confidential. Some of the survey respondents blame quarrying and corruption in anomalous flood control projects. Some experienced psychological trauma, while others are more alert due to past experiences. Contrary to the answers of the residents, the LGU sees urbanization and encroachment as the primary causes of flood risks rather than deforestation or quarrying. The findings highlight a difference in perspectives on the causes of flooding. Residents identify quarrying as a cause, based on firsthand observation of how deforested uplands accelerate runoff and worsen local flooding. The LGU emphasizes urbanization and encroachment, noting that impervious surfaces, subdivisions, and blocked waterways reduce the municipality's overall capacity to absorb water. Nevertheless, these perspectives are not mutually exclusive. Flooding occurs because many factors work together—quarrying, deforestation, and urban development all increase the risk and severity of floods.

3.5.4. Expert opinion.

According to the DENR Climate Change Service (CCS), around 48 million Filipinos are exposed to pluvial flooding, with 18% living in poverty. The country faces high flood risk, with varying levels of adaptive capacity across regions. In Rizal Province, exposure to climate change impacts—including increased temperature, precipitation, sea level rise, and tropical cyclones—is assessed as medium to high. Extreme flooding is largely driven by projected increases in extreme rainfall and the lack of proactive risk management systems and flood control infrastructure. Vulnerable groups during flood events include women, children, people living in poverty, and Indigenous Peoples due to limited access to resources, information, and support systems. A hydrology expert from Pamantasan ng Lungsod ng Valenzuela (PLV) further noted that flooding is influenced by multiple interacting factors, including intense rainfall, rapid population growth, low-lying terrain, reduced soil infiltration from urban development, declining drainage capacity caused by sedimentation, poor urban planning, and ineffective implementation of flood control projects. Both institutions emphasize the

importance of long-term, community-centered flood risk management. DENR-CCS advocates a ridge-to-reef approach that integrates watershed and downstream management, promotes nature-based solutions such as vegetation and green infrastructure, and ensures climate-resilient building practices. Preparedness efforts should focus on targeted information campaigns, community education, and the active participation of vulnerable groups. Communities should also be involved throughout response, rehabilitation, and recovery phases. Meanwhile, PLV highlights the role of collaboration between academe, local government units (LGUs), and communities in strengthening disaster preparedness through workshops, capacity-building programs, and the use of technology for flood monitoring and reporting. The expert also recommends improving public access to flood-related information, including hazard maps, early warning systems, project monitoring reports, and budget allocations through open data platforms, enabling communities to make informed decisions and participate more effectively in flood risk management.

4. Conclusions

In Rodriguez, Rizal, the overall perceived impact of flood risks among vulnerable residents—classified according to age, sex, civil status, residential location (barangay), proximity to waterways, monthly income, length of residency, and educational attainment—was assessed as Medium Risk. Similarly, the overall perceived adaptive capacity of residents to flood risks across these demographic categories was found to be Moderate. Based on the findings of this study, the management capacity of the Local Government Unit (LGU) in addressing flood risks within vulnerable communities was assessed as Low for structural flood risk management and Medium for non-structural flood risk management. To strengthen overall management capacity, improvements in flood control infrastructure and evacuation facilities are necessary, alongside the implementation of a community-engaged system designed to address existing gaps in flood risk management. The results further indicated that residents' engagement in municipal flood risk management was Moderately Engaged in Prevention and Mitigation, Moderately Engaged in Preparedness, Fully Engaged in Response, and Moderately Engaged in Rehabilitation and Recovery. The relatively higher level of engagement in the Response phase suggests a greater reliance on reactive rather than proactive approaches to flood risk management. The Flood Governance Anchored in Transparency and Engaged Society (FLOOD GATES) System was developed based on the findings of this dissertation to address flood vulnerabilities within both the LGU and local communities through a collaborative, community-centered approach. Rather than working solely for the people, the system emphasizes working with the people. Its primary objective is to enhance community engagement by leveraging residents' key motivation—good governance—across all thematic areas of flood risk management, including prevention and mitigation, preparedness, response, and rehabilitation and recovery.

Acknowledgments

I would like to express my thanks to the interviewees/respondents of this study who gave their time and effort to give their valuable inputs.

Author Contribution

This study is conducted by a single author from conceptualization to writing with no external funding support.

Competing Interest

There is no financial, personal, or professional relationships that might influence or appear to influence this research.

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